

ORIGINAL CONTAINS  
COLOR ILLUSTRATIONS

**HYPersonic CFD APPLICATIONS AT NASA LANGLEY  
USING CFL3D AND CFL3DE**

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**N91-10874**

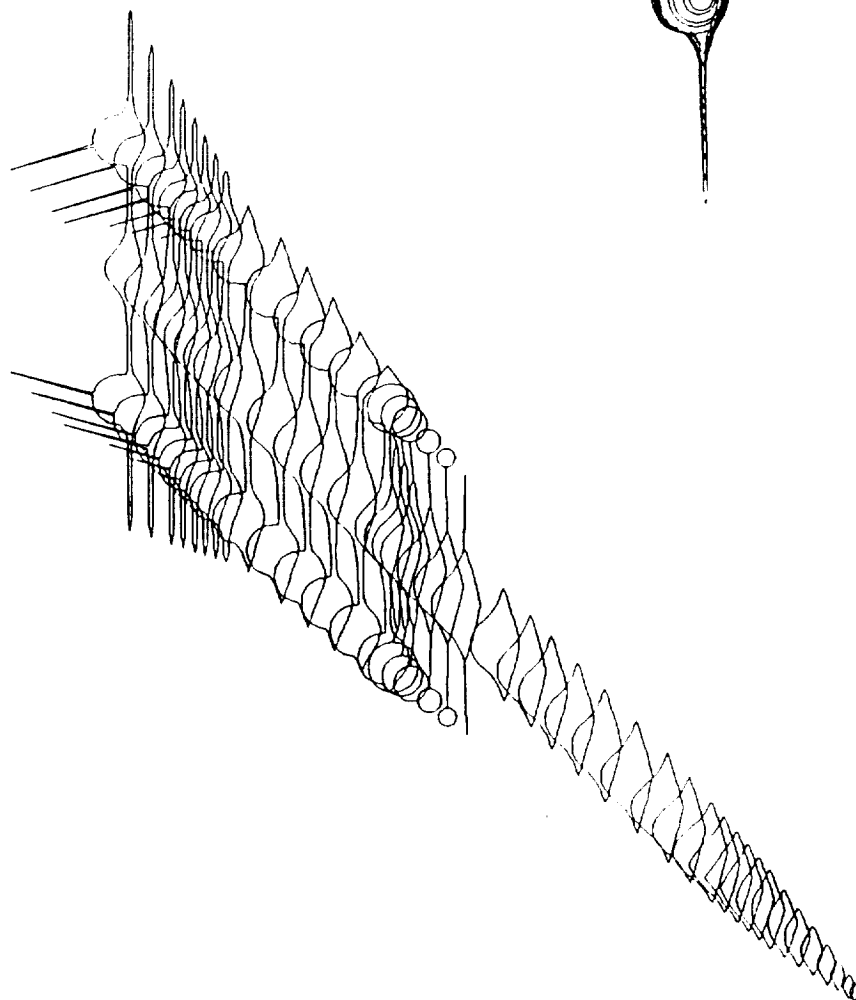
## **CFL3D/CFL3DE**

- Time-dependent conservation law form of compressible Euler and Navier-Stokes equations
- Upwind-biased spatial differencing (Flux Vector Splitting - FVS and Flux Difference Splitting - FDS)
- Thin-layer, finite-volume implementation with algebraic turbulence model
- Zonal grids - longitudinally patched (for hypersonic flows)
  - CFL3D
    - 3-factor implicit time advancement algorithm
    - Thin-layer viscous in 3 directions - two wall corner model
  - CFL3DE
    - Streamwise-relaxation crossflow-AF, space-marching Euler or PNS, first or second order
    - Perfect gas or equilibrium air

## **INDUSTRY USE STATUS OF CODES**

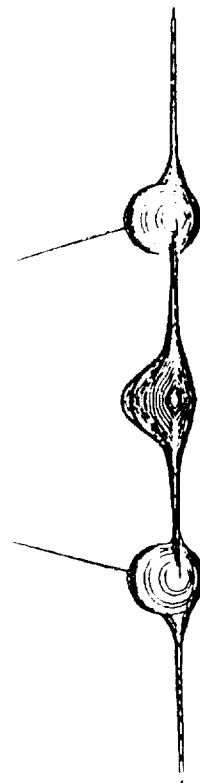
- **NASP prime contractors - all instructed in code use at workshop August 2-3, 1988.**
  - **Production code for NASP for McDonnell Aircraft Company**
  - **Some use at General Dynamics**
- **Other industry use**
  - **Boeing**
  - **Northrup**
  - **United Technologies Research Center**
- **University use**
  - **Iowa State University**
- **Other government use**
  - **Naval Surface Warfare Center**

# SR71 - GEOMETRY DEFINITION



## FOUR ZONES:

- 51X51X23
- 71X51X8
- 71X51X7
- 91X51X4

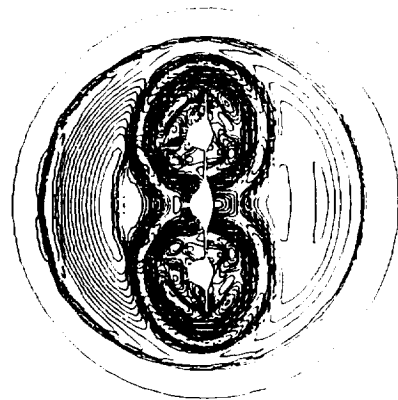
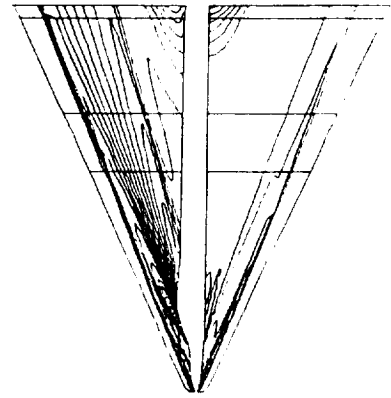
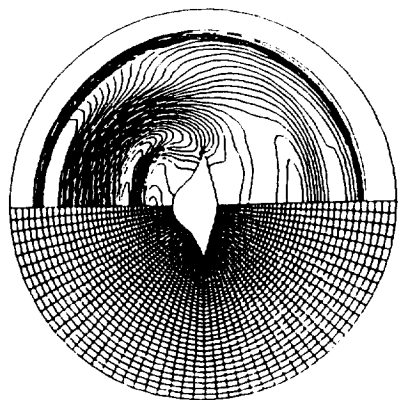
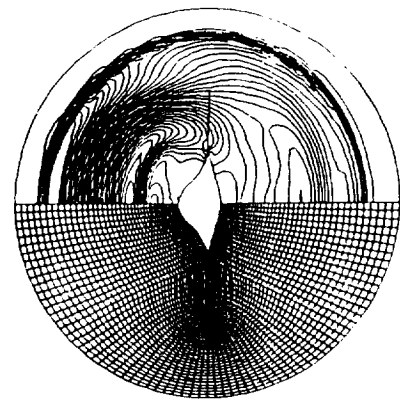
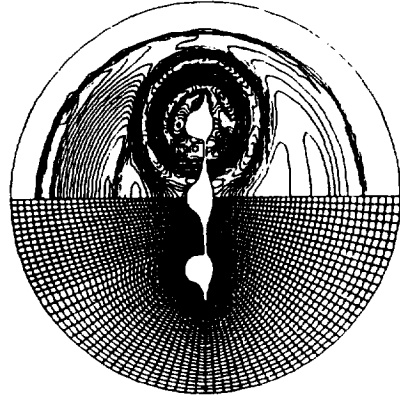


$$M_{\infty} = 3.0 \quad \alpha = 0^{\circ}$$

$$\rho_{\infty} = 0.038 \text{ kg/m}^3 \quad p_{\infty} = 5460 \text{ N/m}^2$$

# SR71 - EQUILIBRIUM AIR EULER SOLUTION

## CROSS-SECTION PRESSURE DISTRIBUTIONS AND GRID DEFINITIONS





# GOVERNMENT BASELINE

Pressure

0.000

0.500

1.000

1.500

2.000

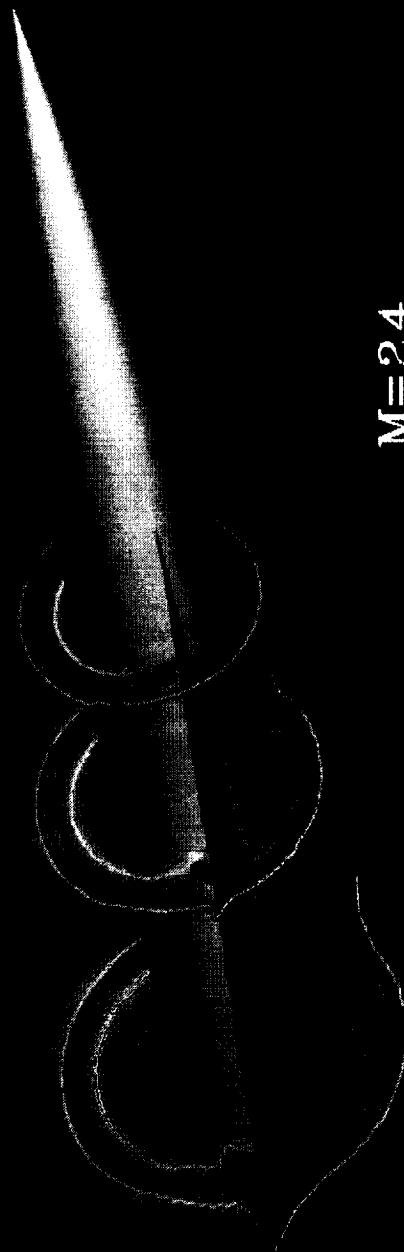
2.500

3.000

3.500

4.000

4.500



$M=24.$

$AOA=1.$

$Re=9000./in$





# HYPersonic LIFTING BODY

TEMPERATURE

0.000

2.000

4.000

6.000

8.000

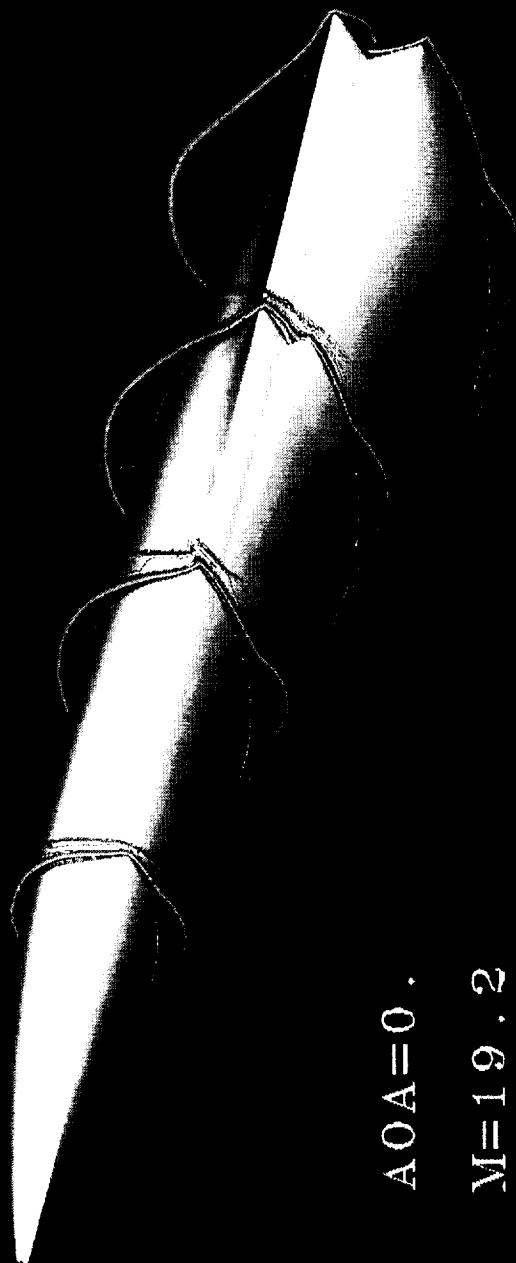
10.000

12.000

14.000

16.000

18.000



AOA=0.

M=19.2

Re=30000/in



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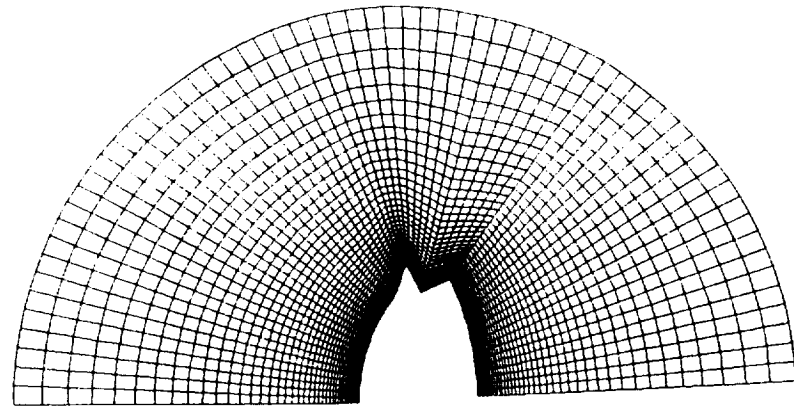
# PARTICLE TRACES

19.200 MACH  
0.00 DEG  
3.00x10++4 R.  
65x65x46 GRID

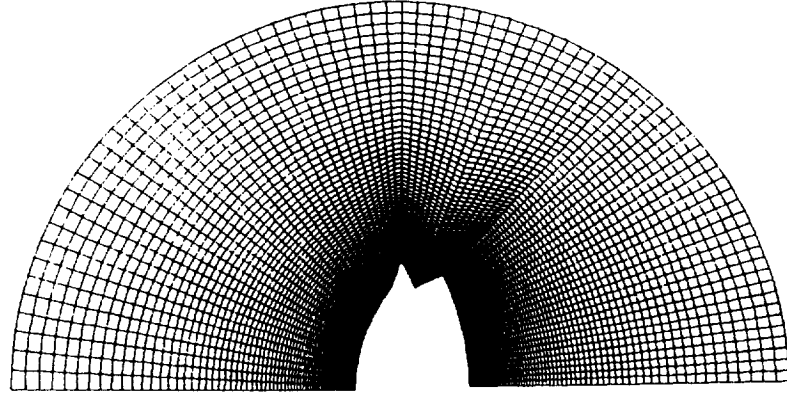


## GRID DENSITY COMPARISON

### CROSS-SECTION 45 (COWL PLANE)



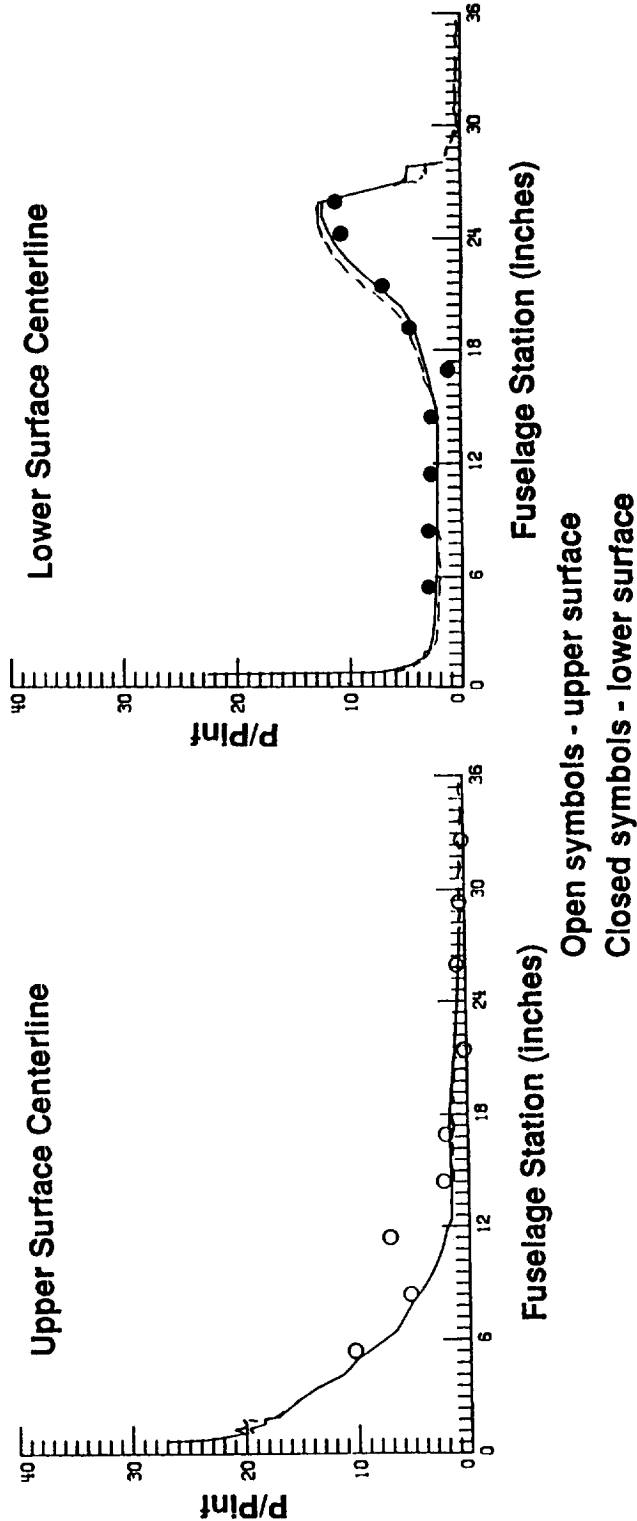
**65 X 65 X 46 GRID  
Y-PLUS ORDER 1.**



**80 X 130 X 56 GRID  
Y-PLUS ORDER .001**

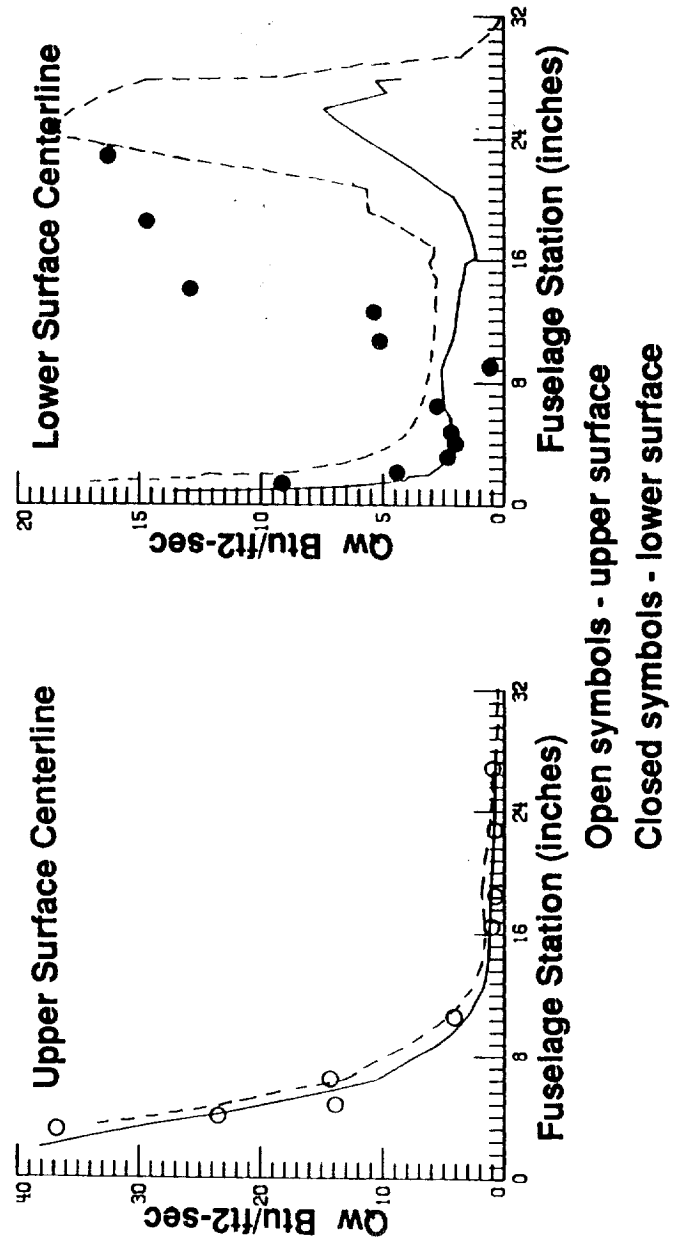
PRESSURE COMPARISONS

M = 12.55  
 Re = 2.7 million/ft.  
 Zero degrees angle of attack



## HEAT TRANSFER COMPARISONS

$M = 12.55$   
 $Re = 2.7 \text{ million/ft.}$   
 Zero degrees angle of attack



**AERODYNAMIC COEFFICIENTS COMPARISON MCDONNELL  
BLENDED WING BODY CFD AND EXPERIMENT**

**M = 12.4,  $\alpha$  = 6°, Re/L = 930,000/ft**

	<b>CN</b>	<b>%ERROR</b>	<b>CA</b>	<b>%ERROR</b>
<b>AFWAL PNS</b>	<b>0.07154</b>	<b>3.1</b>	<b>0.02002</b>	<b>.9</b>
<b>MDC CFL3D</b>	<b>0.06956</b>	<b>5.8</b>	<b>0.01949</b>	<b>3.5</b>
<b>LARC CFL3D</b>	<b>0.07247</b>	<b>1.8</b>	<b>0.02154</b>	<b>6.6</b>
<b>Experiment</b>	<b>0.07382</b>		<b>0.02020</b>	
<b>Experimental Uncertainty</b>		<b>7.5</b>		<b>6.4</b>





DENSITY  
 GENERIC NOZZLE AFTERBODY  
 COMPUTATIONAL METHODS BRANCH NASA LANGLEY

CONTOUR LEVELS

3.987 MACH  
 0.00 DEG ALPHA  
 2.34x10\*\*5 Re  
 63x12x40 GRID 1  
 28x12x40 GRID 2

0.0000  
 0.02500  
 0.05000  
 0.07500



TEMPERATURE  
 GENERIC OPTION #2 : 2-D INLET MODEL  
 COMPUTATIONAL METHODS BRANCH NASA LANGLEY

CONTOUR PLOTS

12.500 MACH  
 0.00 DEG ALPHA  
 9.40x10\*\*4 Re  
 1.0 TIME  
 95x30x51 GRID

1000000  
 1000000  
 1000000



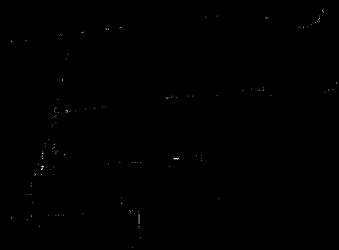
MACH NUMBER

30 DEG SWEEP MACH 3.5 INLET

COMPUTATIONAL METHODS BRANCH NASA LANGLEY

CONTOUR LEVELS

3.500	MACH
0.00 DEG	ALPHA
0.35x10+7	Re
31x72x19	GRID 1
72x31x19	GRID 2
31x72x15	GRID 3



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## **FUTURE PLANS RELATED TO THE NATIONAL AERO-SPACE PLANE PROGRAM**

- **Continue to expand the envelope of capabilities for the code to include calculations of an entire NASP-like configuration**
  - **Improved zonal capabilities for inlets with sweep and combustors**
  - **Addition of non-equilibrium chemistry for combustor and nozzle/afterbody calculations**
  - **All capabilities scheduled for production code by 1/90 (NASP Technology Maturation Program)**

